the upper one. The distance from c to the upper summit (see drawing) was about 75°; from c to the sun, 30° approximately. For a few moments at this time a faint, colored arc (b in fig. 1) was visible in the southwest sky at about 45° distance from the sun and apparently concentric to the halo; it displayed the colors of the spectrum in good definition with the red appearing on the side nearer the sun.

The halo and tangent arcs continued visible until 3:10 p. m., when a covering of alto-cumulus clouds had obscured the whole phenomenon.

EXPERIMENT ON SUNSET COLORS.[1]

By F. W. JORDAN.

[*Reprinted from* Science Abstracts, Sec. A, Oct. 25, 1915, §1403.]

The purity of color in a diffraction halo[2] depends essentially on the size of the condensed droplets. The author describes a simple experiment in which the motion and distribution of the different-sized water droplets in a cloud are partially controlled. The colors obtained on illuminating the cloud with sunlight are comparable with those of soap films and present the features of sunset colors. It is concluded that some of the brilliancy and extensiveness of sunset colors is due to a quiescent state or regular motion of the clouds or mist at sunset and also to a distribution into layers of droplets of nearly uniform size.—*T. Harris.*

HALO OF MAY 20, 1915, ANALYZED.

By Prof. CHARLES SHELDON HASTINGS.

[Dated: Sloane Laboratory, Yale University, Oct. 25, 1915.]

[Early in September of this year Mr. A. M. Comey, of the Eastern Laboratory, Du Pont Powder Co., Chester, Pa., sent this Bureau two very interesting photographs of the solar halo of May 20, 1915, as seen at Chester, Pa. (lat. 39° 50′ N.; long. 75° 20′ W.). The first view, shown in figure 1, was taken at 11:15 a. m. (75th mer.) with a Zeiss wide-angle lens of Series 5, using stop 64 and 1/100 second exposure. The second photograph was taken at 11:45 a. m., and showed the features reproduced in figure 3. In this REVIEW for May, 1915, we presented a large photograph of the corresponding halo seen at New Haven, Conn.; Mr. Comey's photographs are of additional interest, since they record the parhelic circle as well as the circumscribed halo of 22°. Unfortunately these photographs were unable to record the brilliantly colored arc of the 46°-halo, reported from both localities, although figure 3 was extensive enough to have included it.

Both photographs from Chester have been studied and analyzed by Prof. Hastings and the results are communicated below.—C. A., jr.]

A careful study of Mr. Comey's photographs of the halo of May 20 yields a remarkable amount of exact conclusions. These I shall endeavor to make clear.

It is to be observed that the photographs are, in a sense, not true pictures of what one might have seen, but are in reality a projection on a plane of lines in a concave sky—linear dimensions, not angles, are recorded. Did we know the exact focal length of the lens used it would be easy to deduce the angles from the linear dimensions. Nevertheless, it is possible to deduce the focal length from the pictures themselves with all requisite precision.

Focal length of camera.

We are justified in assuming that the middle of the plate is in the axis of the camera as employed. If this is so, it is clear that all great circles passing through the corresponding point in the sky would appear in the photograph as straight lines in this point, which we may designate by P. The angular distance from P to any point on one of these lines is given by the equation

$$F \tan \alpha = d,$$

where d is the measured distance by any scale and F is the focal length in the same units. Moreover, according to any theory of halos the angular distance separating the highest point of the halo from the lowest point is very nearly 44 degrees; or for a photographic view, in which violet light is most effective, we may estimate this distance as equal to 44.6 degrees. These considerations and direct measurement of the photograph give us the following set of equations for the photograph of figure 1:

$F \tan \alpha = 1.48$ in., $F \tan \beta = -4.15$ in., $\alpha - \beta = 44.6°$.

The corresponding equations for the photograph of figure 3 are as follows:

$F \tan \alpha = 4.30$ in., $F \tan \beta = -0.64$ in., $\alpha - \beta = 44.6°$.

The only uncertainty here depends on our assumption as to the adjustment of the camera and my own estimate as to the position of the beginning of the brightest portion of the ring. The solution of the first equations gives $F = 5.54$ in. and of the second $F = 5.51$ in., values in sufficiently close agreement.

Circumscribed halo and parhelic circles.

The position of the zenith in figure 2 is pretty accurately fixed, since the parhelic circle is well defined and that portion near the sun is so close to P that it is little distorted. My estimate from this plate makes the zenith distance of the sun equal to 26.1°. The zenith distance of the sun at the time the second photograph was taken is not so easily found, chiefly because of the faintness of the image of the parhelic circle. My conclusion from measures freed from distortion is a zenith distance in this case of 21.5°, which can not be far from the truth.

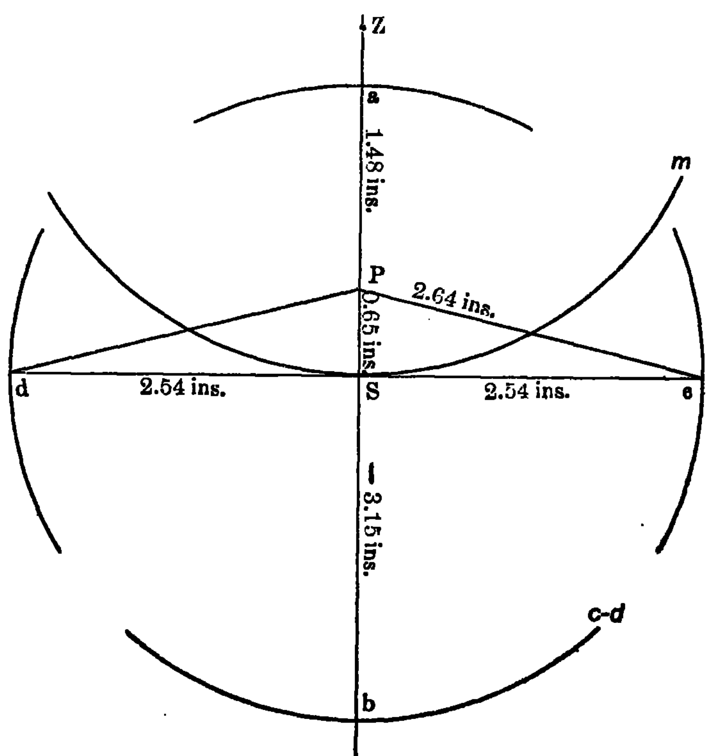

FIG. 2.—Analysis, by Prof. C. S. Hastings, of the original large print reproduced on a smaller scale in fig. 1. The dimensions refer to those of the original print.

The horizontal semidiameter, Sc, of the circumscribed halo is found as follows:

Angular distance P to c (or d) is 25.5°, since $F \tan 25.5° = 2.64$ inches.

Angular distance P to S is 6.7°, since $F \tan 6.7° = 0.65$ inch.

[1] Nature (London), July 29, 1915, 95:590-591 [2] Better termed "corona."—C. A., jr.

(Contributed by A. M. Comey.)

FIG. 1.—Solar circumscribed halo of 22° of 1915, May 20, photographed at Du Pont Powder Co.'s plant, Chester, Pa., at 11:15 a. m. Note almost complete parhelic circle. Sun's zenith distance, 21.5°.

(Contributed by A. M. Comey.)

FIG. 3.—Solar circumscribed halo of 22° of 1915, May 20, photographed at Du Pont Powder Co.'s plant, Chester, Pa., at 11:45 a. m.

Note arc of parhelic circle, which was longer and more distinct in the negative; also failure to photographically record the colored inferior arc of the 46°-halo reported by the observer. Sun's zenith distance, 21.5°.

The measured angle included between these two lines is 75.1°. The third side of the spherical triangle is therefore equal to 24.6°, which is the quantity sought.

of this feature. This fact is not at all surprising since the arc, although conspicuous on account of the purity of its coloring, was a very faint object in comparison with

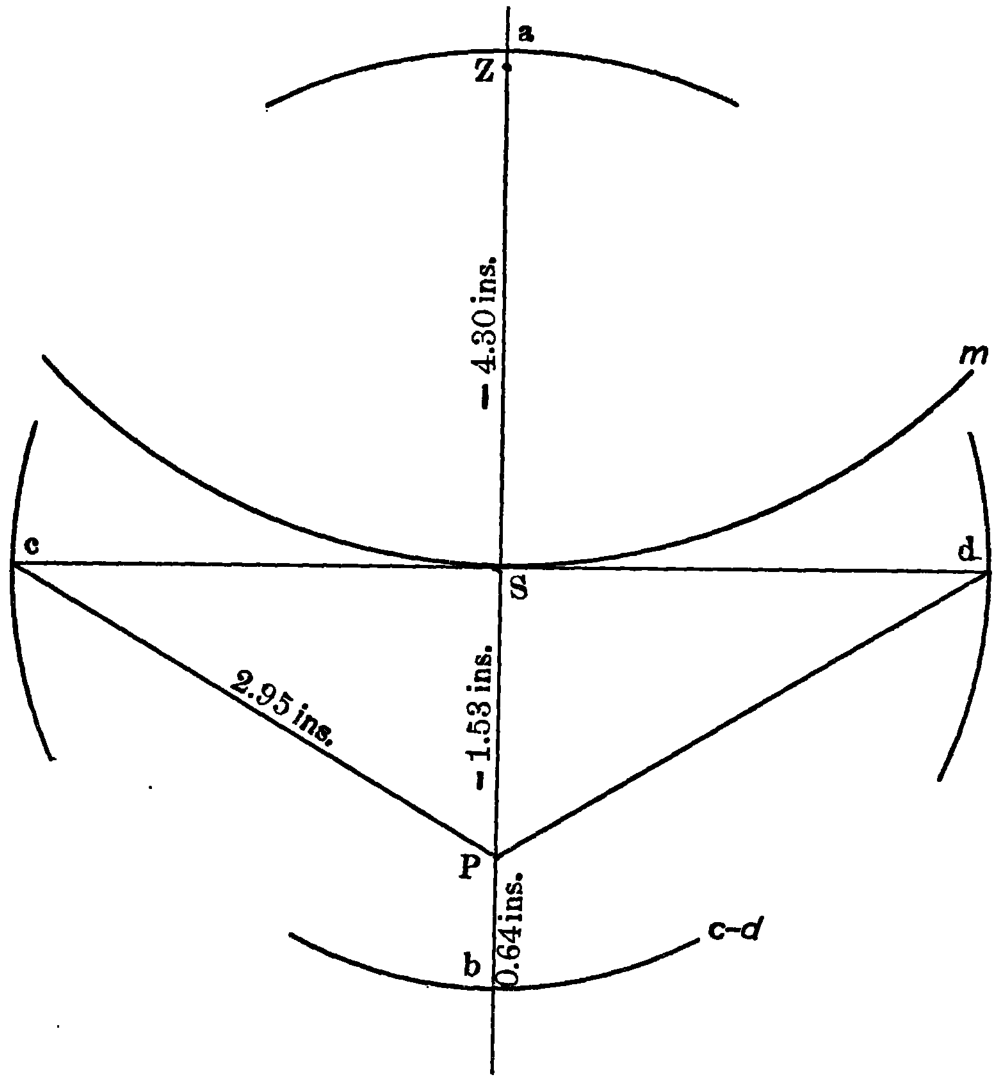

FIG. 4.—Analysis, by Prof. C. S. Hastings, of the original large print reproduced on a slightly smaller scale in fig. 3. The dimensions refer to those of the original print.

The corresponding elements of the triangle in figures 3 and 4 are

P to *c* (or *d*), 28.16°; included angle 59.04°,
P to *S*, 15.52°,

whence third side equals 23.9°.

According to the theory of Venturi, the values of the third side should be 24.5° and 23.8°, respectively. A more convincing proof that the brilliant ring here photographed was in fact the circumscribed halo of 22° (sometimes called Oval of Venturi) could not be demanded. In this connection it may be added that measurements which I have made on Mr. York's photograph[1] taken in this city, yield 23.8° for the angular distance of the east and west points of the oval from the sun at the time it was taken. This also is the theoretical value. I inclose sketches (figs. 2 and 4) of my interpretation of the two photographs, the points chosen in the halo being at the inner edge of the brightest portions.

In the second of Mr. Comey's photographs (fig. 3) the region of the arc of the 46°-halo is depicted with no trace of this feature. This fact is not at all surprising since the arc, although conspicuous on account of the purity of its coloring, was a very faint object in comparison with the splendid circumscribed halo. The same photograph also shows the parhelic circle with a higher sun than has hitherto been recorded, although exceedingly faint. The change in the luminosity of this circle during the half hour which separated the two photographs (figs. 1 and 3) is very significant. According to the generally accepted theory, which explains it by ordinary reflection from the larger surfaces of oriented crystals, it ought to have grown continuously brighter; the explanation which I have offered[2] attributes it to internal total reflection from the smallest surfaces of oriented crystals and this rapid diminution in intensity as the sun rises above 68° [to zenith distances less than 22°] is a necessary consequence.

The scientific interest in the above results lies in two facts: (1) They record a smaller parhelic circle than any heretofore observed; (2) they show that a photograph properly interpreted gives more accurate measures in this field than we can get in any other way.

[1] See this REVIEW, May, 1915, 43:215, plate opposite.

[2] *Hastings, Charles S.* Light. New York, etc., 1902. Pp. 139-153.